$\theta \rightarrow \alpha$ Phase Transition in Thermally Grown Aluminas: Mechanisms and Control

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Motivation

- Structural components operating at high temperatures (e.g., turbine blades) rely on thermally grown oxides for corrosion protection.
- For longer lifetime operation and higher operating temperatures, improved oxides are needed.
- For this purpose, improved understanding of oxide growth mechanisms is needed.

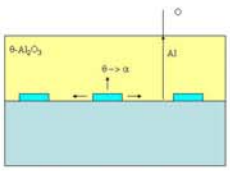
Introduction

- The first formed oxide is θ-Al_2O_3 which transforms to α-Al_2O_3 at T>1000C.
- But corrosion protection is provided by α-Al_2O_3 .
- The probability of failure increases with oxide thickness.
- Thus, it is desirable to accelerate the transformation to keep oxide thin.

Accomplishment

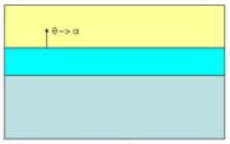
- We establish that the early stage θ-phase development is strongly influenced by the presence of external nucleation sites and that these sites can be exploited to dramatically reduce θ-phase growth.
- We determine that fine particles of α-Al_2O_3, trapped in the sample surface during the final step in the sample polishing procedure, will act as nucleation sites.
- We present a simple model that provides an excellent quantitative description of the oxide evolution.

Model: Oxidation of β-NiAl at 1100 C



I

θ-Al_2O_3(yellow) forms before α-Al_2O_3 and grows rapidly. The oxide grows at the top surface (Al outward diffusion). α-Al_2O_3 (blue) subsequently nucleates and grows at the buried Interface by $\tilde{\theta}\square\alpha$ conversion.

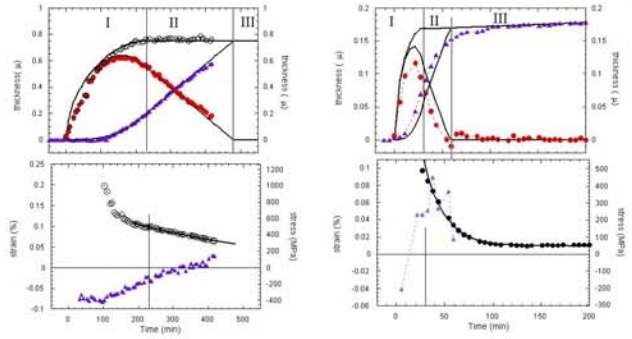


II

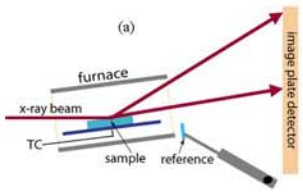
α-Al_2O_3 at buried interface cuts off outward flow of Al atoms. When metal/oxide interface becomes completely covered with α-Al_2O_3, the growth of θ-Al_2O_3 stops and new oxide growth is α-Al_2O_3 that results from $\tilde{\theta}\square\alpha$ conversion.

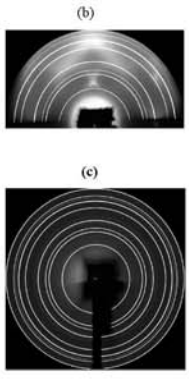
III

When θ is totally consumed, α-Al_2O_3 scale grows much more slowly at metal/oxide interface (steady state growth).



Left panels: oxide thickness, α and θ phase strains for diamond polished sample.
Right panels: same for alumina polished sample. For the alumina polish, conversion is much more rapid leaving a thinner oxide when conversion is complete. Strains are initially tensile in α-Al2O3, compressive in θ-Al2O3. Solid lines are model calculations

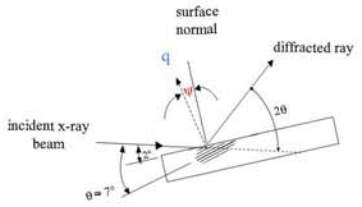




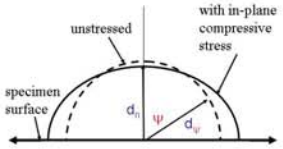
(a) Schematic of the experimental setup.

(b) Half rings of α-Al_2O_3 reflections from oxidized NiAl sample. Strain is obtained from elliptical distortion of rings.

(c) Full α-Al_2O_3 Debye-Scherrer rings from the alumina reference.



In-situ measurements at APS



With in-plane stress, Debye-Scherrer diffraction rings are elliptically distorted.

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